ABSTRACT

Remote Controlled Orbiter Capability

The Remote Control Orbiter (RCO) capability allows a Space Shuttle Orbiter to perform an unmanned re-entry and landing. This low-cost capability employs existing and newly added functions to perform key activities typically performed by flight crews and controllers during manned re-entries. During an RCO landing attempt, these functions are triggered by automation resident in the on-board computers or uplinked commands from flight controllers on the ground. In order to properly route certain commands to the appropriate hardware, an In-Flight Maintenance (IFM) cable was developed. Currently, the RCO capability is reserved for the scenario where a safe return of the crew from orbit may not be possible. The flight crew would remain in orbit and await a rescue mission. After the crew is rescued, the RCO capability would be used on the unmanned Orbiter in an attempt to salvage this national asset.

Remote Control Orbiter Capability

AIAA Briefing

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RCO Abstract

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Author Bio's

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Mr. Garske has almost 23 years of combined experience in NASA working for the Space Shuttle Program in engineering, operations, and management from two NASA centers - Kennedy and Johnson Space Centers. He earned his B.S. in Technical Physics and A.A. in Astronomy from Southwest Missouri State University in 1983 and a M.S. in Engineering Management from University of Central Florida in 1990. He is the Senior Project Manager for the Orbiter Project Office and is the Project Manager for RCO. He's earned many NASA awards including the NASA Exceptional Service Medal and the NASA Space Flight Awareness Award.

Rafael de la Torre – Boeing IDS, Space Exploration Division

Mr. de la Torre has over 9 years experience in the Space Shuttle Program as a contractor at the Kennedy and Johnson Space Centers. He has been analyzing the Space Shuttle Orbiter Entry GN&C system and Orbiter entry and landing performance for the last 7 years. In addition to his analysis activities, his current responsibilities include ownership of several flight software functions related to the entry GN&C system, including approach and landing guidance and the head-up display. He earned his B.S. in Aerospace Engineering from Embry-Riddle Aeronautical University in 2000 and M.S. in Physics from The University of Houston - Clear Lake in 2007. He has been a key contributor to developing, implementing and testing GN&C-related software modifications in support of RCO.

Introduction

- Initial assumption or risk is that the Orbiter Tile Protection System (TPS) could suffer damage such that re-entry with flight crew would be too risky, even if repaired
- The Space Shuttle Program (SSP) Mission Management Team (MMT) would declare a Safe Haven and begin crew rescue operations via another shuttle launch
- Meanwhile, the “compromised” Orbiter would be a surrogate to the stranded crew and ISS crew and its resources depleted to minimum required to support a re-entry/breakup for an ocean ditch
- Space Shuttle Program was searching for easy concept to retrieve/recover a compromised Orbiter and not discard a valuable asset
- The Remote Control Orbiter (RCO) capability was developed and implemented to provide the SSP the capability to land the Orbiter without a flight crew in an emergency situation
  - Uses the Autoland functionality
- The Space Shuttle Program has requested a capability to recover the vehicle in lieu of an ocean ditch when a Safe Haven has been declared – Salvage operation

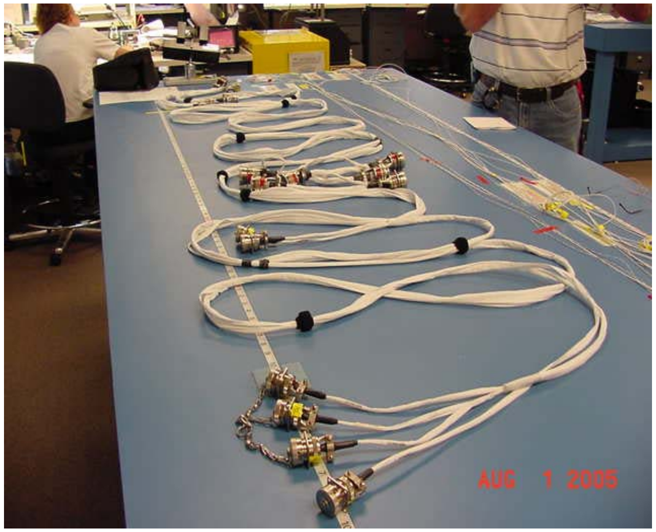
Overview

- The Orbiter flight deck panels that are used to manually control the following functions were targeted to be reconfigured:
  - APU start/run
  - Air Data Probe (ADP) deploy
  - Main Landing Gear (MLG) arm/down
  - Drag Chute arm/deploy
  - Fuel Cell reactant valve closure
- The reconfiguration is accomplished by the flight crew performing an In-Flight Maintenance (IFM) procedure to install a pre-fabricated cable and loading special software designed to support capability
- RCO IFM installs a cable to provide electrical connectivity from Ground Control Interface Logic (GCIL) avionics box up to the flight deck panel switches
  - Enables ground controllers to control the targeted functions via command uplink
  - Allows flight software to control certain targeted functions
- The cable is 28 feet long, weighs 5.4 lbs, and is stowed on the ISS for emergency use
- RCO IFM Cable with its supporting flight software change will provide the SSP the capability to land the Orbiter without a flight crew in an emergency situation

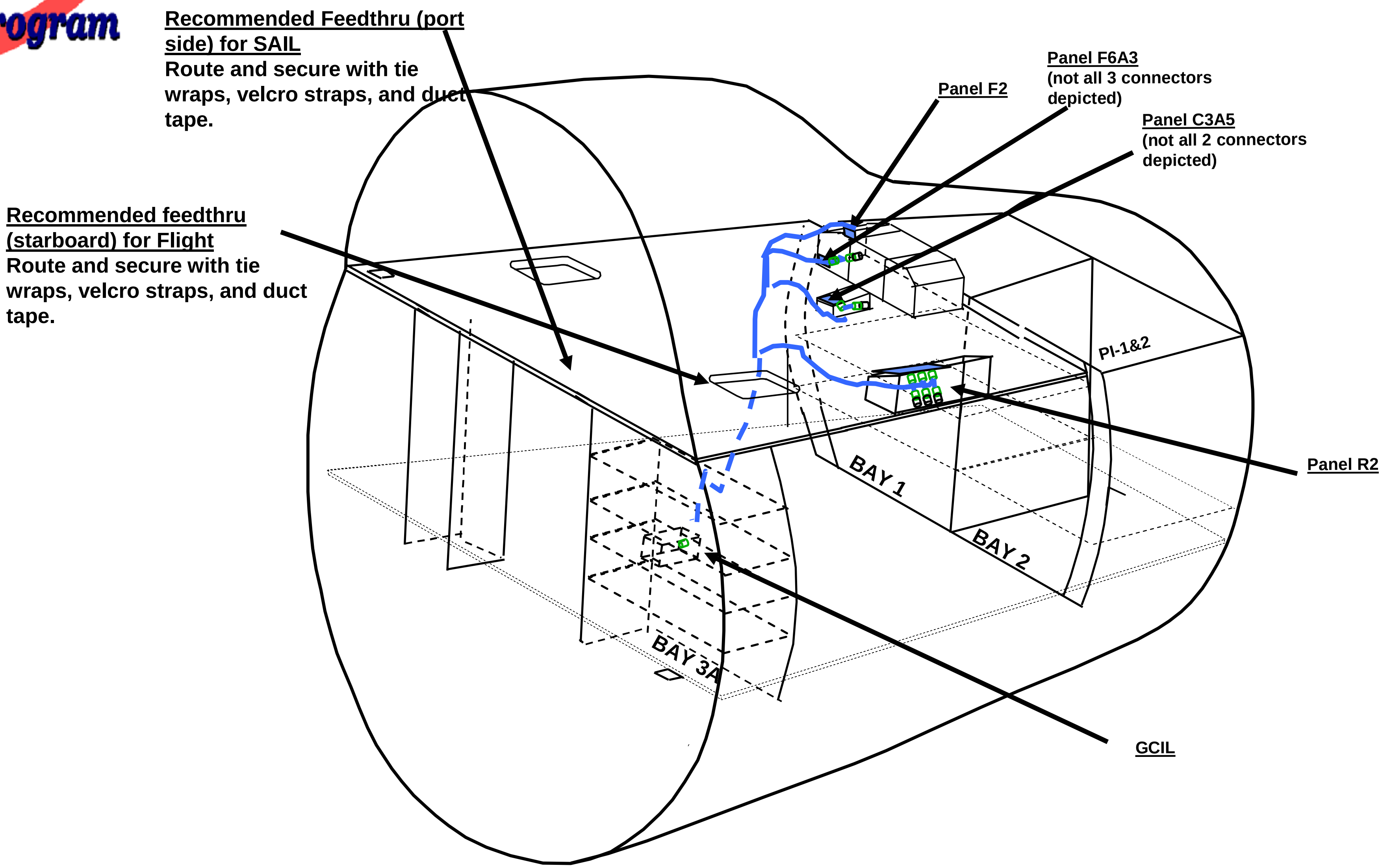
Program Design Groundrules

- RCO IFM Cable supports an emergency contingency operation
- RCO IFM Cable must be single fault tolerant for functions that:
  - Affect crew safety (while docked or during undocking operations)
  - Affect the safety of people on the ground
- Zero fault tolerance for RCO IFM Cable functions that protect from loss of Vehicle
- The landing site shall be Vandenberg.
- Systems certification is not performed.
- The RCO Cable shall be installed as an In Flight Maintenance (IFM).
- SAIL functional verification testing shall be performed
- Build one cable for flight and one for SAIL.
  - Stow one flight cable onboard ISS.

RCO Cable

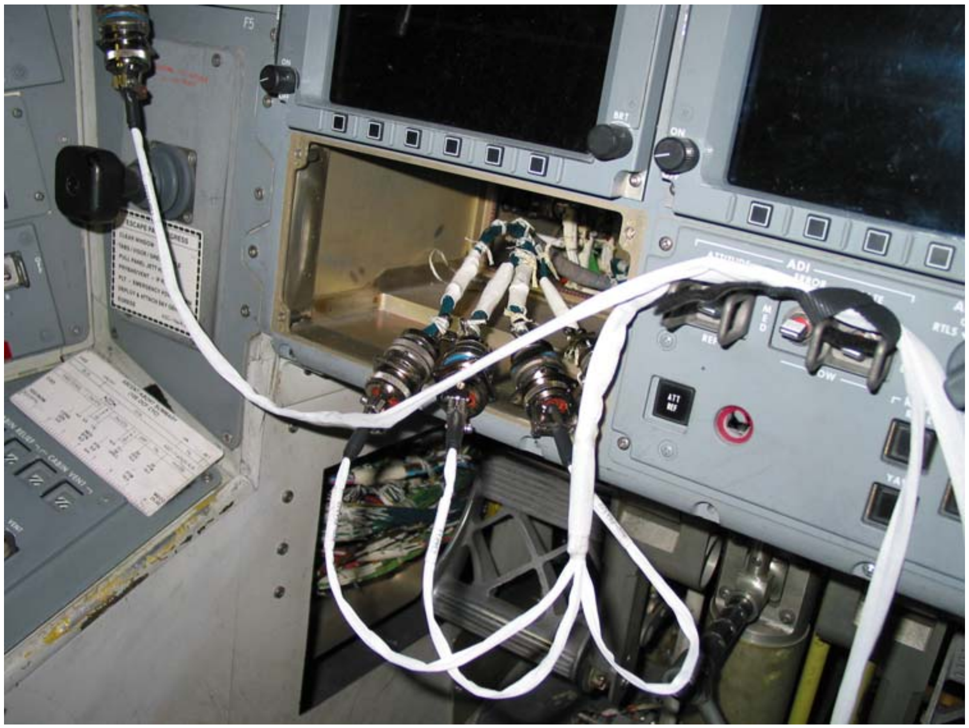


RCO IFM Concept

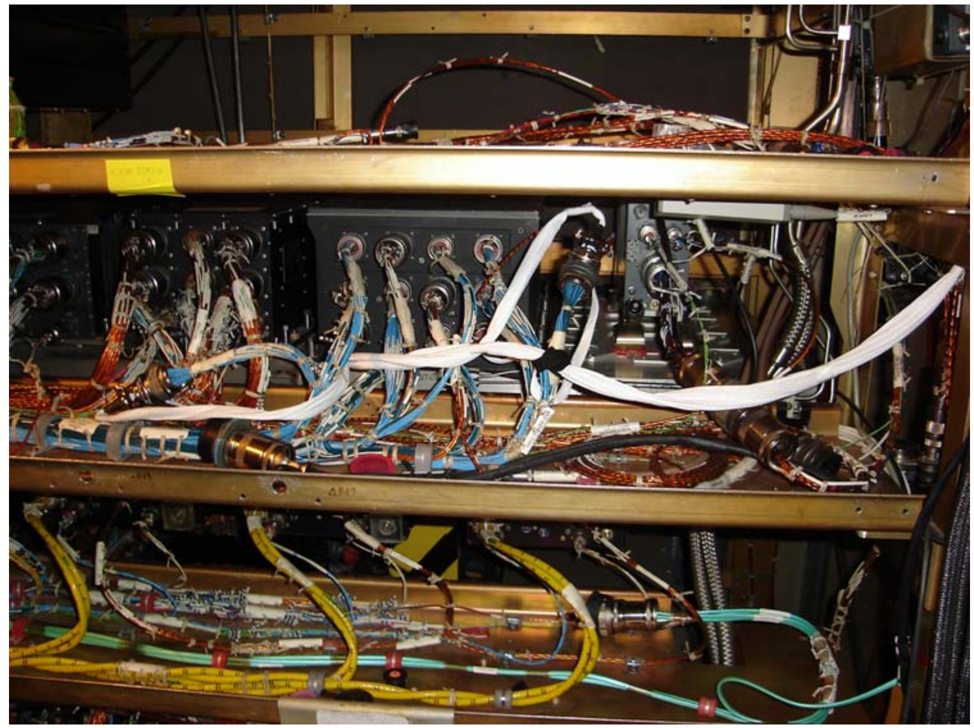


- One RCO IFM cable for SAIL to support integration of hardware/software avionics testing, IFM verification and one cable for flight

RCO Cable Routing



PNL F6A3 (Landing Gear Controls)



Middeck Avionics Bay 3A GCIL hookup

RCO Flight Software

- **SW changes targeted only necessary items**
  - Critical and could not be uplinked
  - Time-critical commands
- **Changes implemented via phased approach**
  - OI-30 STS-117
    - Special Flight Software patch
    - OMS Burn enable window expansion for Deorbit burn (15 sec – 3 min)
    - State Vector info transfer from G3 to S2 during entry ops for antenna management
  - OI-32 STS-120
    - OI-30 changes baselined in FSW
    - RCO Inhibit/Enable ITEM entry added to display for activation of FSW functions
  - OI-33 TBD
    - Automates landing gear and drag chute arm & deploy
    - Incorporates GPS during rollout for lateral tracking

SAIL Testing (OV-095)

- History making event…First time G3 and S2 GPC memory configuration combination was used for entry and landing
- Verified Flight Software mods are ready to support STS-117 with OI-30
- Verified Flight Software mods are ready to support STS-120 with OI-32
- Verified hardware interfaces (voltage and current levels)
- Test run of IFM installation and procedure with STS-121 Crew
- Also, undock and back away steps, including PLBD closure via manual uplink commands were run and validated

Unique Ops Guidelines

- Orbit SM controlling PL MDMs through landing (No BFS loaded/running)
  - Supports Antenna Management for communications
  - Supports PLBD closure
  - Hardware configuration constraints prevent use of BFS
  - SM is more robust operating system
- Vandenberg selected as landing site
  - Lowest risk to the public or ground resources due to water approach
  - Needs MLS equipment installed to support autoland software
  - Orbiter FSW mods (OI-33) enable GPS during landing rollout
- Autoland GNC capability will be utilized
  - Approach & Landing pitch and roll guidance
  - Automated landing gear and drag chute deploy (OI-33)
  - Auto derotation and nose-wheel steering during rollout

Ops Overview

- On Orbit - Safe Haven Declared, Salvage the Orbiter
  - Docked with ISS
  - Some level of TPS repairs could be performed
  - Prepare Orbiter for remote controlled capability
    - Perform IFM’s (undock and RCO) and cockpit switchlist (entry)
    - Enable RCO Flight Software
  - Crew Egress to ISS, close and secure hatch
    - Handover Orbiter control to MCC ground flight controllers
  - Undock & Separate Orbiter from ISS
    - Ground uplinks DEU’s normally performed by crew keyboard entries

Ops Overview Continued

- Pre-DeOrbit Burn setups
  - Configure GPC's to G3/S2 memory configuration (Note: no BFS)
    - Load and activate TFL 172 downlink telemetry format (normally 164)
  - Uplink and load DeOrbit targets
  - Uplink Stored Programmed Commands
    - SPC's are uplinked and stored onboard for timed execution…ground uses trajectory prediction tools to predict the time for execution of the following RCO functions:
      - Air Data Probes Deployment
      - Landing Gear Deployment (OI-30, OI-32)
      - Drag Chute Deployment (OI-30, OI-32)
      - Fuel Cell Shutdown
  - Close Payload Bay Doors
  - Start three APU's via Real Time Command uplink

Ops Overview Continued

- Perform De-Orbit Burn
  - Command GPC's to GNC Major Mode 303 and to SM Major Mode 201
  - APU's to norm Press (HYD Pressure to normal) via uplink RTC
  - Command GPC's to GNC Major Mode 304
- Entry Interface, 400,000 ft.
- At Mach 5, the Air Data Probes deploy via onboard SPC
- At Mach 2.5 enter the TAEM interface
- Approach and Landing interface at Touchdown minus ~80 seconds
- At 2000 ft., the Landing Gear is armed and deployed *
- Touchdown
  - Arm and deploy drag chute*
  - Auto derotation and steering (using GPS in OI-33)
- Landing Rollout complete
  - Orbiter Power down via onboard SPC to close Fuel Cell Reactant valves

*via onboard SPC through OI-32, Automated for OI-33

Risks/concerns

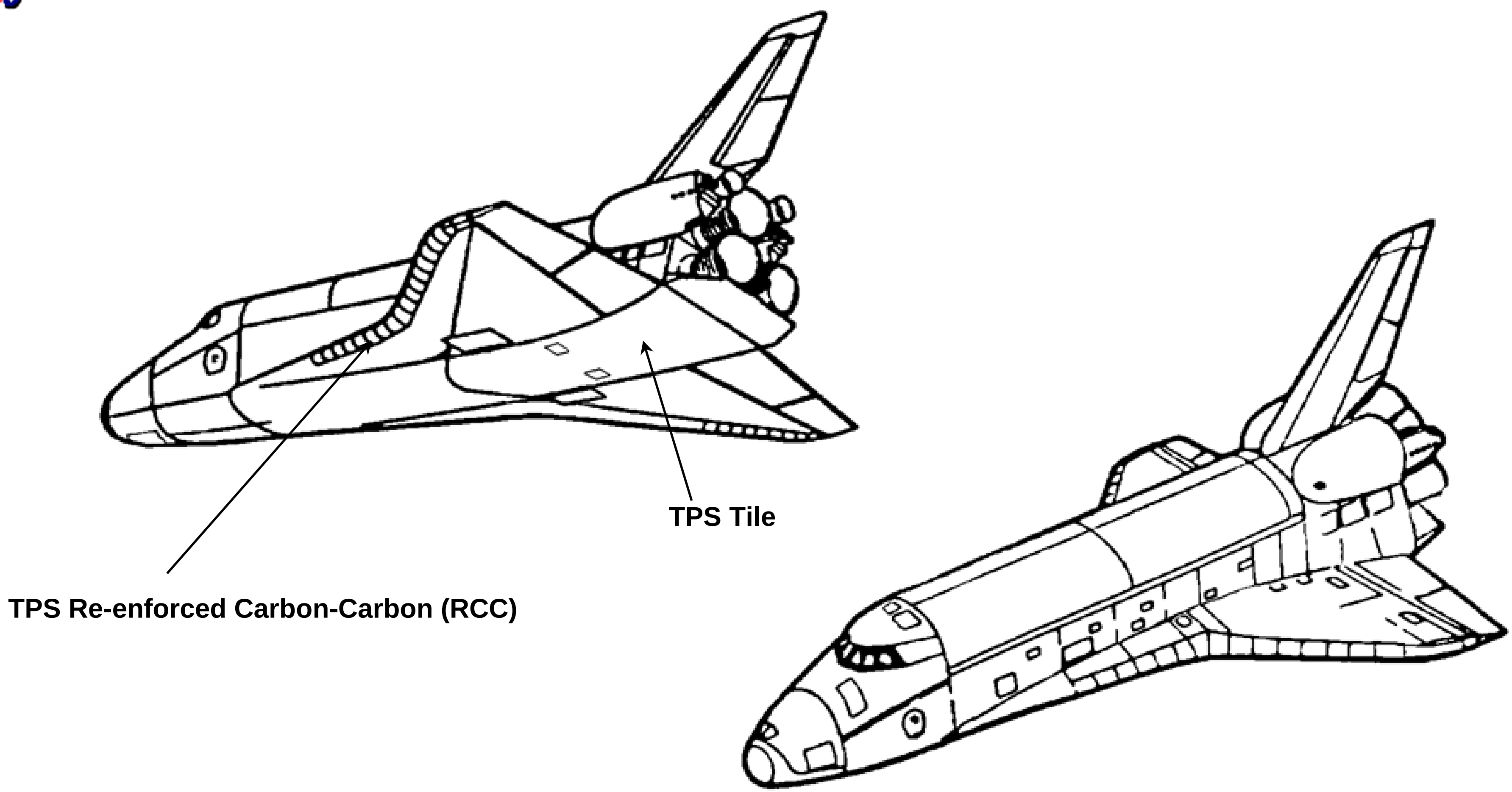
- None at the Cable level
- Only partial checkout capability prior to use can be accommodated on-orbit
- Overflight risk NOT an issue for MMT and Agency with water approach to Vandenberg
- Vandenberg support facilities near runway could sustain damage
- RCO IFM Cable loss of function/result table:

Function	Loss Of Function/Action	Result
Start APUs	Activate 3 prior to de-orbit burn. If 2 of 2 APU strings do not activate, execute ocean ditch	Loss of Orbiter in ocean
Deploy Air Data Probe	If air data probes fails to deploy, take Navigation Derived Air Data	Potential loss of Orbiter within landing site
Arm, Deploy Landing Gear	Should gear fail, then landing will be with gear up	Loss of Orbiter on runway and potential facilities damage
Deploy Drag Chute	If Drag chute fails to deploy, then runway rollout will be long	Exceeding runway length may cause damage to Orbiter
Emergency Power Down	Fuel cell(s) expected to overheat, if heat rejection lost, prior to running out of cryo while still producing power.	Potential loss of Orbiter on runway due to Fuel Cell overtemp.

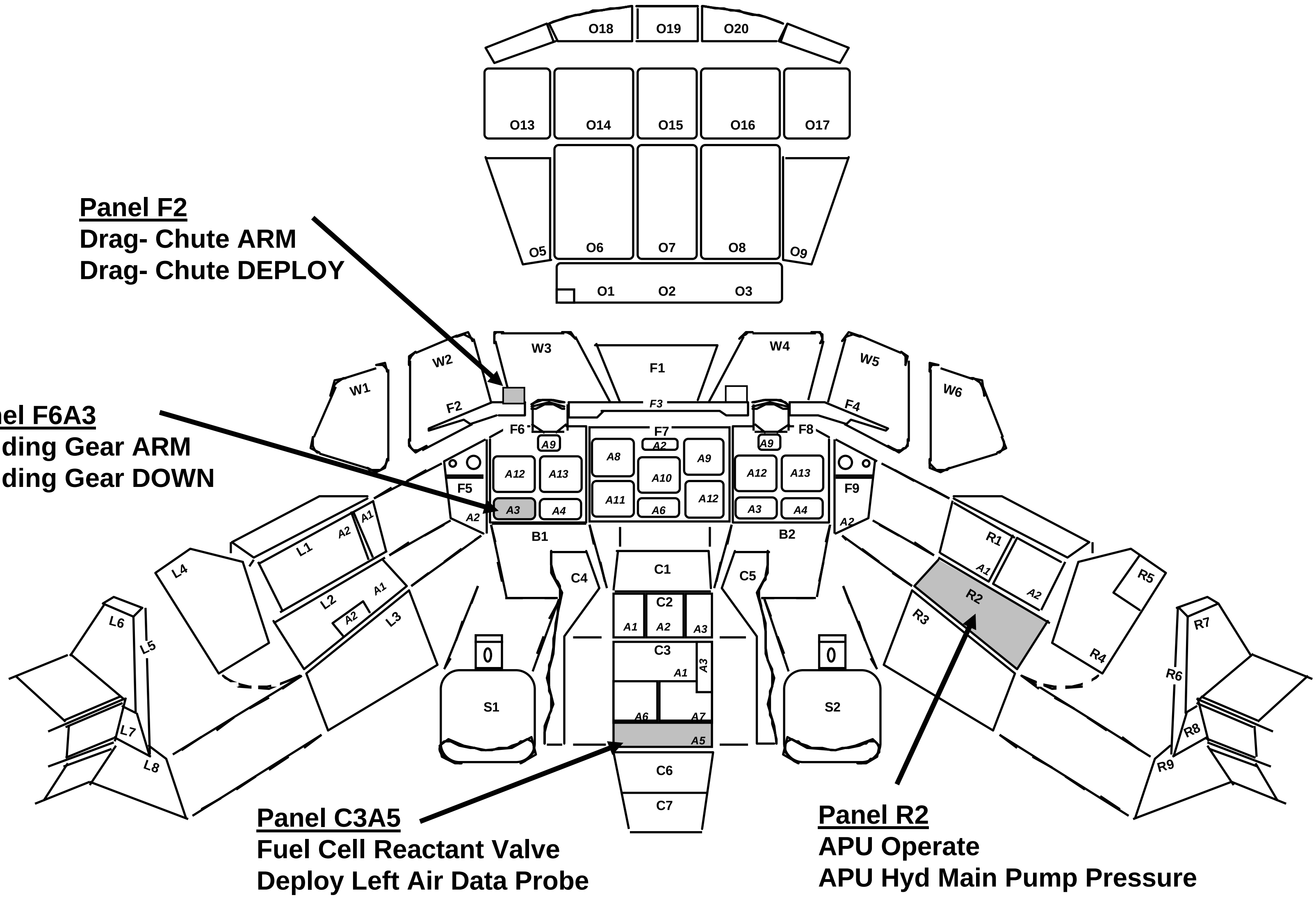
Summary

- The RCO IFM Cable with its supporting flight software change will provide the SSP the capability to land the Orbiter without a flight crew in an emergency situation
- The RCO IFM Cable and concept provides the benefit of recovering a high valued asset in lieu of discarding in the ocean

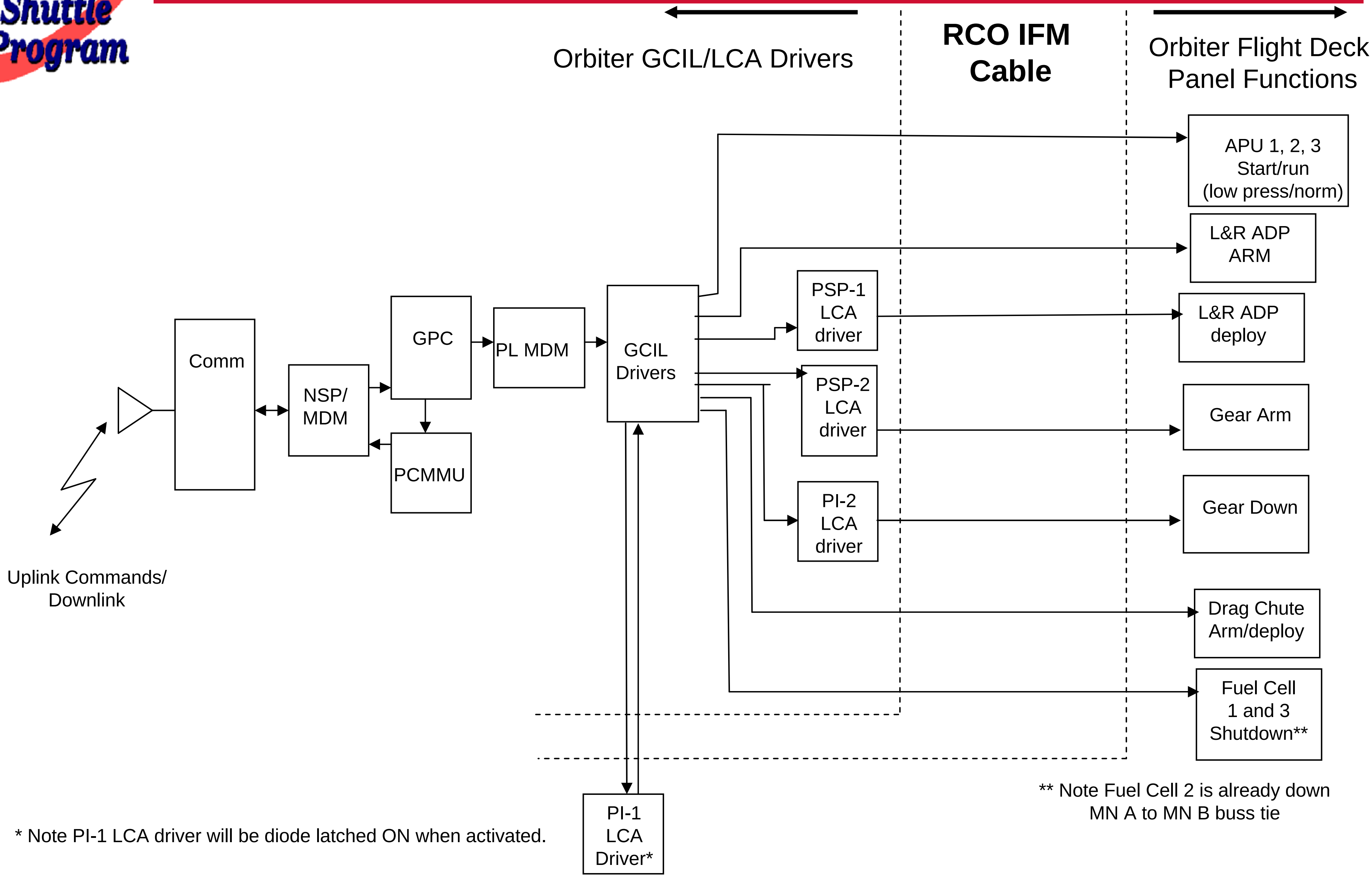
Backup


TPS Tile
TPS Re-enforced Carbon-Carbon (RCC)

Panels Accessed



Command/driver Overview



* Note PI-1 LCA driver will be diode latched ON when activated.

** Note Fuel Cell 2 is already down MN A to MN B buss tie

RCO Cable Design Analysis

- FMEA bent pin analysis performed
- Orbiter system circuit analysis performed
- Hazard analysis performed
- Materials certification completed
- Parts derating analysis performed
- EMI analysis performed

RCO Cable Hardware

- RCO IFM Cable parts list (one cable)
  - 16 connectors with pins, backshells, and caps
  - ~800 ft 22AWG Nickel coated wire (MIL-W-22759/12-22-9)
  - 5 diodes (JANTX1N4942)
  - splices
  - Gortex outer jacket for cable protection
  - Velcro straps
  - Other small hardware misc…

RCO Operational Guidelines

- Other than the initial orbiter TPS damage causing Safe Haven, all other orbiter systems are fully functional
  - Avionics and Flight Control Systems redundancy not changed except:
    - PL1 MDM J6 demated due to Contingency Shuttle Crew Support (CSCS) IFM
- Risk assessment for Vehicle survivability during re-entry is somewhere between re-entry with crew onboard and ocean ditch
- Use Safe Haven IFM undocking approach
- Tasks historically performed by the Crew accommodated by;
  - Ground uplink (RTC's and DEU Equivalents)
  - Ground uplink Stored Program Commands (SPC's) to accommodate time critical events
- Crew will install IFM hardware and pre-configure necessary switches
- The Orbiter is ready to be commanded, re-enter, and land remotely, via ground control once the RCO IFM is installed
- Autoland functionality is NOT affected

RCO Timeline

Event	Time	Task
Pre-Undock Preparation	Pre-Undock	IFM Installation
		Configure DPS, GPC 5 to SM OPS 2 (SM MM 201)
		Ku-Band Antenna Stow
		APU Config
		Deactivate Star Trackers and close doors
		H2O Loop Config
		FES Checkout
		OMS/RCSConfig
		NWS Enable
		FES/NH3 Config
		Configure for Payload Bay Door closing
		Configure TCS
		Hydraulic Sys Config
		Close Hatches
Separation Maneuver	Undock	Fire Aft Pitch RCS jets burst - attain 0.22 fps vel
	Undock + 9 sec	Universal Pointing Item 21 at 2 ft separation
	Undock + 2 min	Open DAP deadbands to configure for free drift
	Undock + 32 min	Close DAP deadbands
Reboost Maneuver		Maneuver to reboost burn attitude
	Undock + 42 min	Perform posigrade +X reboost burn
Maneuver to comm attitude	TIG - 80 min	Maneuver to communications attitude
Configure DPS for Entry	TIG - 70 min	GNC GPCs to MM 301

RCO Timeline Cont'd

Uplink Deorbit Targets	TIG - 30 min	Uplink deorbit targets
Uplink SPCs		Uplink SM Stored Program Commands
Transition to GNC MM 302	TIG - 25 min	Uplink Cmd GNC GPCs to MM 302
Transition to SM MM 202	TIG - 24 min	Uplink Cmd SM GPC to MM 202
Load Deorbit Targets	TIG - 20 min	Uplink Load deorbit targets
Maneuver to Deorbit Attitude		Maneuver to deorbit attitude
Close Payload Bay Doors	TIG - 15 min	Uplink SM OPS 202 Cmd to close Payload Bay doors
Start APU 1, 2 and 3	TIG - 5 min	Cmd APU 1, 2, and 3 Start – Uplink RTC
Deorbit Burn Exec	TIG - 60 sec	Uplink deorbit burn Exec Cmd
	TIG	Perform deorbit burn
Transition to GNC MM 303	EI - 15 min	Uplink Cmd GNC GPCs to MM 303
		Uplink Cmd GPS to Nav Auto
Transition to SM MM 201	EI - 14 min	Uplink Cmd SM GPC to MM 201
APUs Press	EI - 13 min	APUs to Norm Press – uplink RTC
Maneuver to EI - 5 Attitude	EI - 10 min	Uplink Cmd to maneuver to EI - 5 attitude
Cmd GNC GPCs to MM 304	EI - 5 min	Uplink Cmd GNC GPCs to MM 304
Entry Interface	EI	Entry Interface, h = 400,000 ft
Deploy Air Data Probe	M = 5	Arm and Deploy Air Data Probe - SM SPC
TAEM Interface	M = 2.5	TAEM Interface
Approach and Landing Interface	TD - 80 sec	Approach and Landing Interface
Arm/Deploy Landing Gear	h = 2000 ft	Arm and Deploy Landing Gear - SM SPC
Touchdown	TD	Touchdown
Arm/Deploy Drag Chute	TD + 7 sec	Arm/Deploy Drag Chute - SM SPC
Orbiter Powerdown	Rollout complete	Cmd Fuel Cell Reactant Valves Closed - SM SPC